High-resolution X-ray diffraction and grazing incidence X-ray reflectivity analyses of nanostructured porous silicon

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SUBJECT AND OBJECTIVES

- **Porous silicon layer (PSL) formation by stain etching and its structure control as a function of doping level, p-type and crystalline orientation.**
- **Structural characterization of PSL by grazing incidence X-ray reflectivity as a function of etching time.**
- **Study of the nanoporosity as a function of etching parameters.**
- **Characterization of PSL by X-ray diffraction as a function of etching time.**
- **Study of the strain in PSL a function of etching parameters.**
- **Structural characterization of PSL by high-resolution X-ray diffraction .**

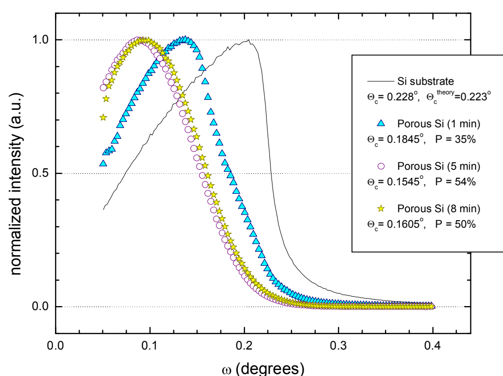
SAMPLE PREPARATION

POROUS SILICON LAYER

- **Silicon p^+ (100), boron doped, 10^{18} atoms/cm^3, resistivity of 0.01 to 0.02 W.cm.**
- **Stain etching HNO_3: HF (500:1) + $NaNO_2$ (0.1 g/L).**
- **Etching time varying at 1 t0 10 minutes**

CHARACTERIZATION BY GRAZING INCIDENCE X-RAY REFLECTIVITY

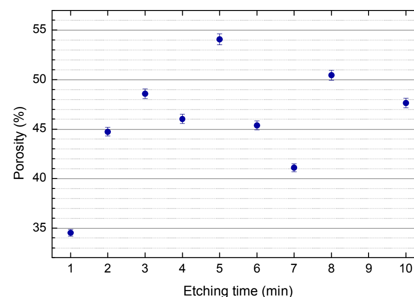
The X-ray reflectivity spectra



The porosity of the porous material can be determined by the following relation:

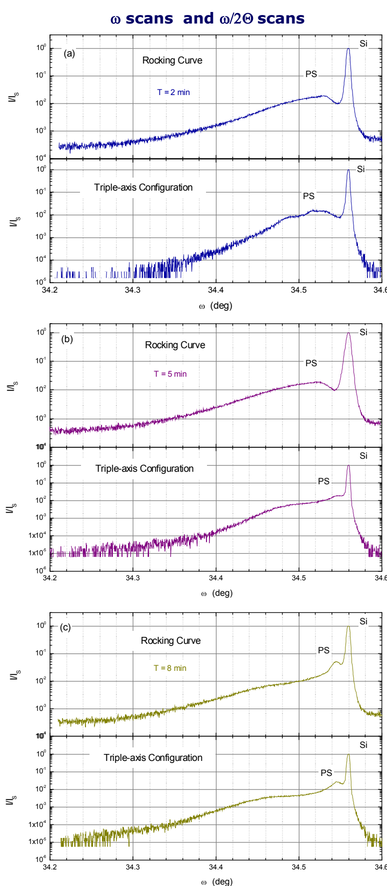
$$P_0 = 1 - \left(\frac{\omega_{c,PS}}{\omega_{c,Si}} \right)^2$$

where $\omega_{c,PS}$ is the critical angle of the PS layer and $\omega_{c,Si}$ is the critical angle of bulk silicon (0.223º for the $CuK_{\alpha 1}$ radiation).



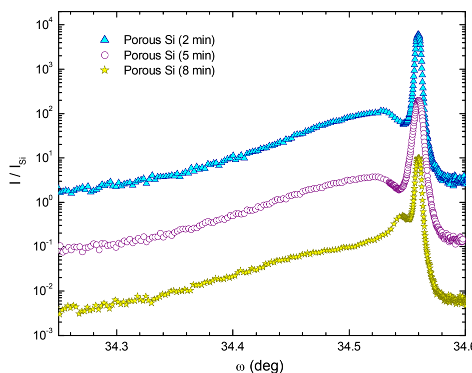
Porosity obtained from the value of the PS critical angle versus the etching time.

ω scans and ω/2Θ scans

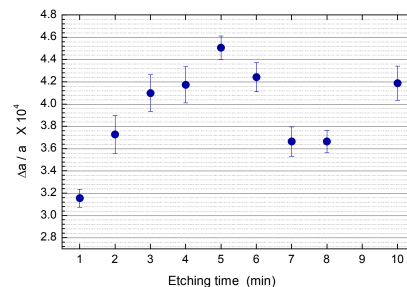


CHARACTERIZATION BY HIGH-RESOLUTION X-RAY DIFFRACTION

The Rocking curve (ω scans)



The strain obtained by the lattice mismatch for PS layer



The relative expansion $\Delta a/a$, where Δa is the difference between the porous layer and the silicon bulk lattice parameter, is directly proportional to the angular splitting $\Delta\omega$ between both peaks:

$$\frac{\Delta a}{a} = -\frac{\Delta \omega}{\tan \Theta_{Si}}$$

where Θ_{Si} is the (004) Bragg angle of the bulk Si.

CONCLUSIONS

- **The results showed that the porosity and the compressive stress increase for etching time up to 5 min and then this tendency is replaced by an oscillatory behavior.**
- **The results showed also that the variation in the porosity and in the stress is directly correlated with the crystallite size distribution in the PS layers as a function of etching time.**
- **The observed morphology is directly correlated with the lattice mismatch controlled by the solution concentration and the etching time.**
- **Stain etching can be to guarantee the use of PS layer as substrate for growing epitaxial narrow gap semiconductor films.**

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